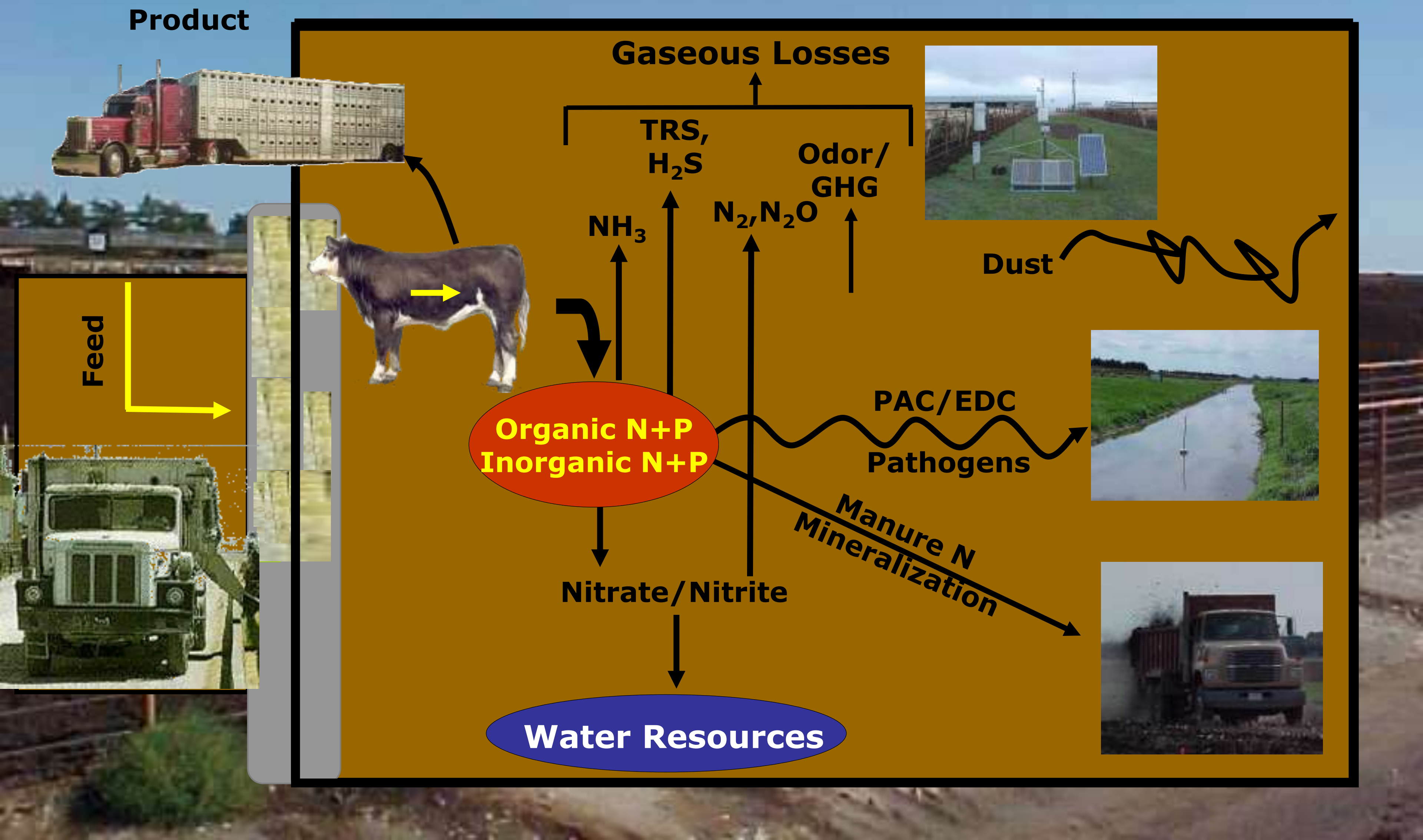
U.S. Meat Animal Research Center

Environmental Management Research Unit
Animal Waste Management Group
Clay Center, NE

D. Parker, R. Eigenberg, V. Varel, M. Spiehs and B. Woodbury

Controlling Environmental Impact from CAFOs

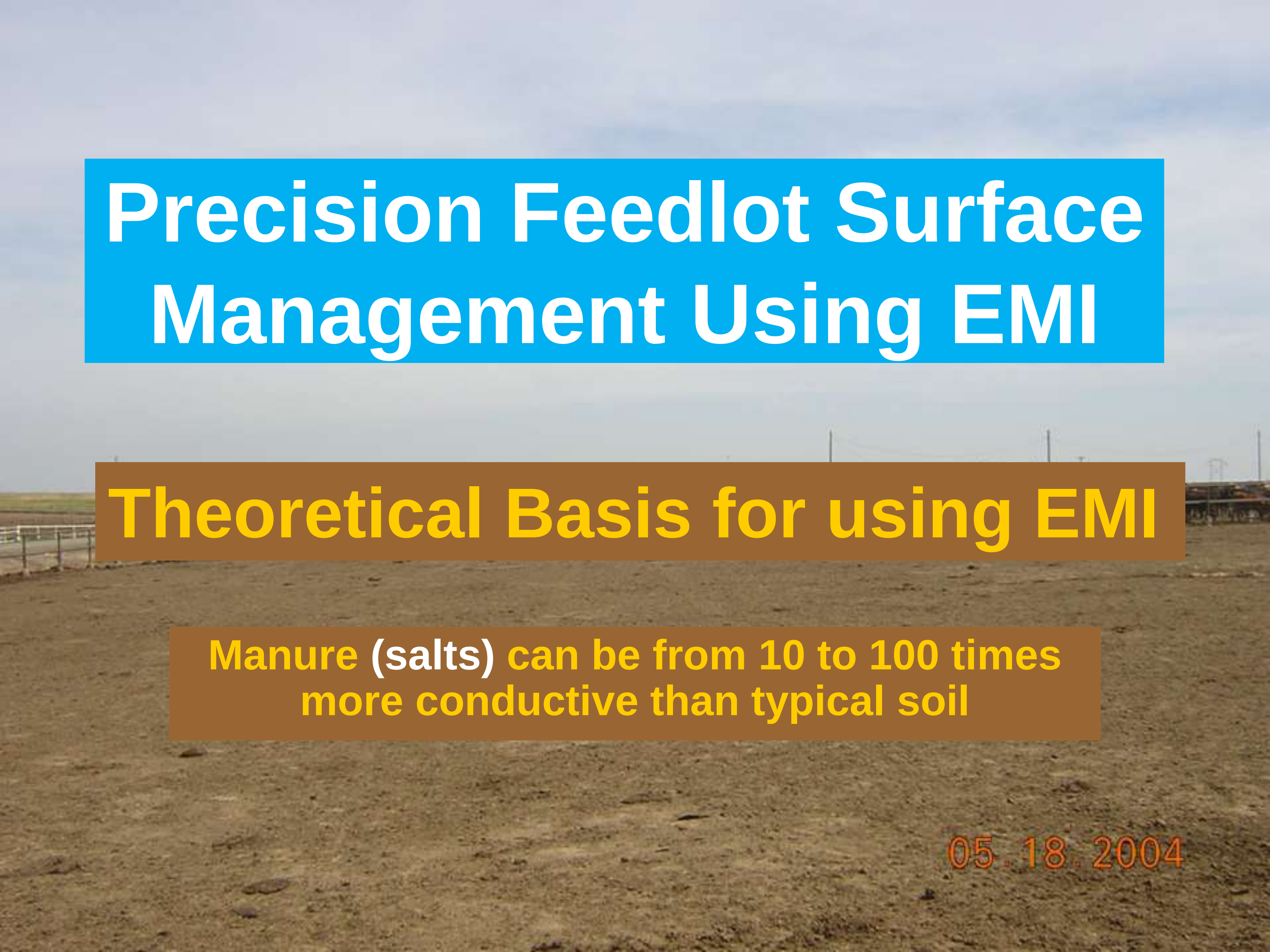
Precision Feedlot Surface Management



Precision Feedlot Surface Management Using EMI

Theoretical Basis for using EMI

Manure (salts) can be from 10 to 100 times more conductive than typical soil



EMI is a powerful tool that can provide insight to unseen conditions that drives environmental quality

How can we harness this tool?

Feedlot Surface Gas Emission

EMI used to address four questions

1. **What kind of emissions (GHG, Odor, PM)?**
2. **How much emissions (i.e. flux rates) ?**
3. **Where are the emissions coming from (i.e. spatial distribution)?**
4. **What can we do about it (management)?**

Develop Method using EMI for Managing the Feedlot Surface

Specific research objectives were:

1. Assess the accuracy of a RSSD, with a stratified random sampling (SRS) procedure for calibrating EMI/soil property regression equations.
2. Test the ability of a regression model estimated using a RSSD for evaluating spatial manure accumulation.
3. Evaluate feedlot surface data for any spatial manure accumulation structure.
4. Establish a methodology for measuring spatially variable chemical/physical constituents associated with manure accumulation on feedlot pen surfaces

Two Sampling Designs

EC_a Data with GPS Coordinates → **Sampling Design**
1. Stratified Random Sampling (SRS)
2. Response Surface Sampling Design (RSSD)

→ **Sample Locations** co-located w/EMI
Cokriging reduces to MLR

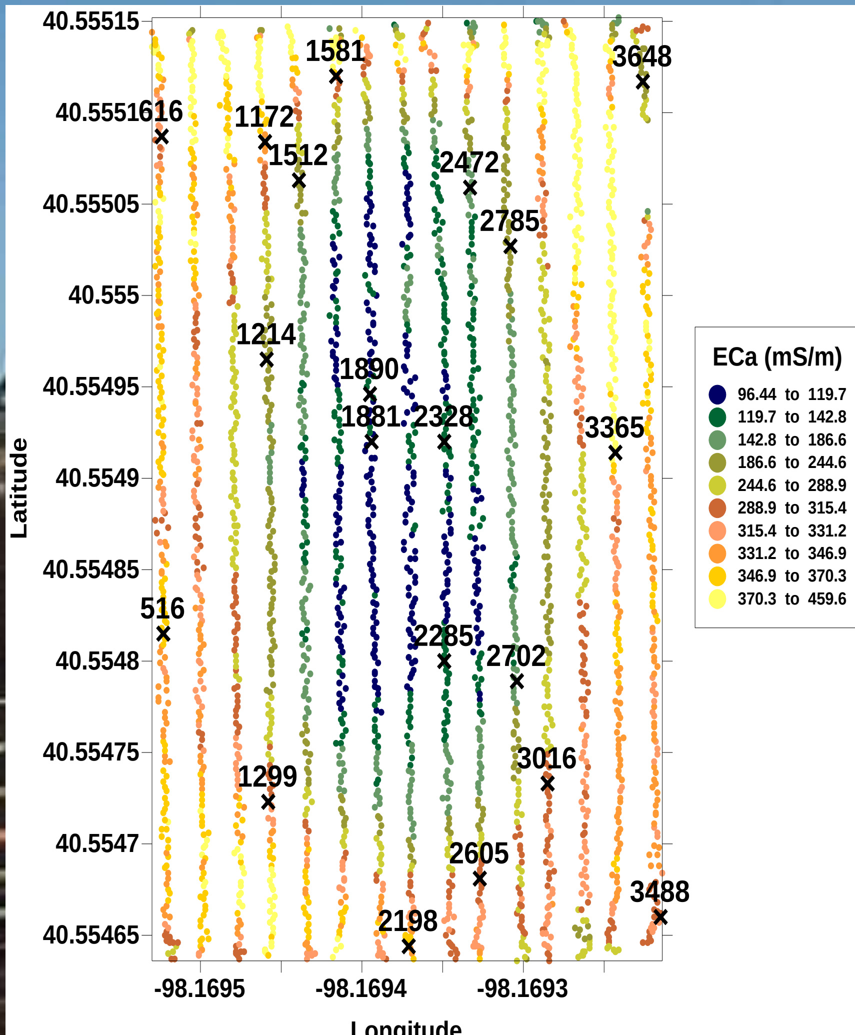
Stratified Random Sampling (20 sites)

- Rank EC_a values from highest to lowest.
- Divided rank into 4 equal segments
- Random number generator to select 5 values from each segment.
- Use GPS coordinates to co-locate soil sample with EC_a value.

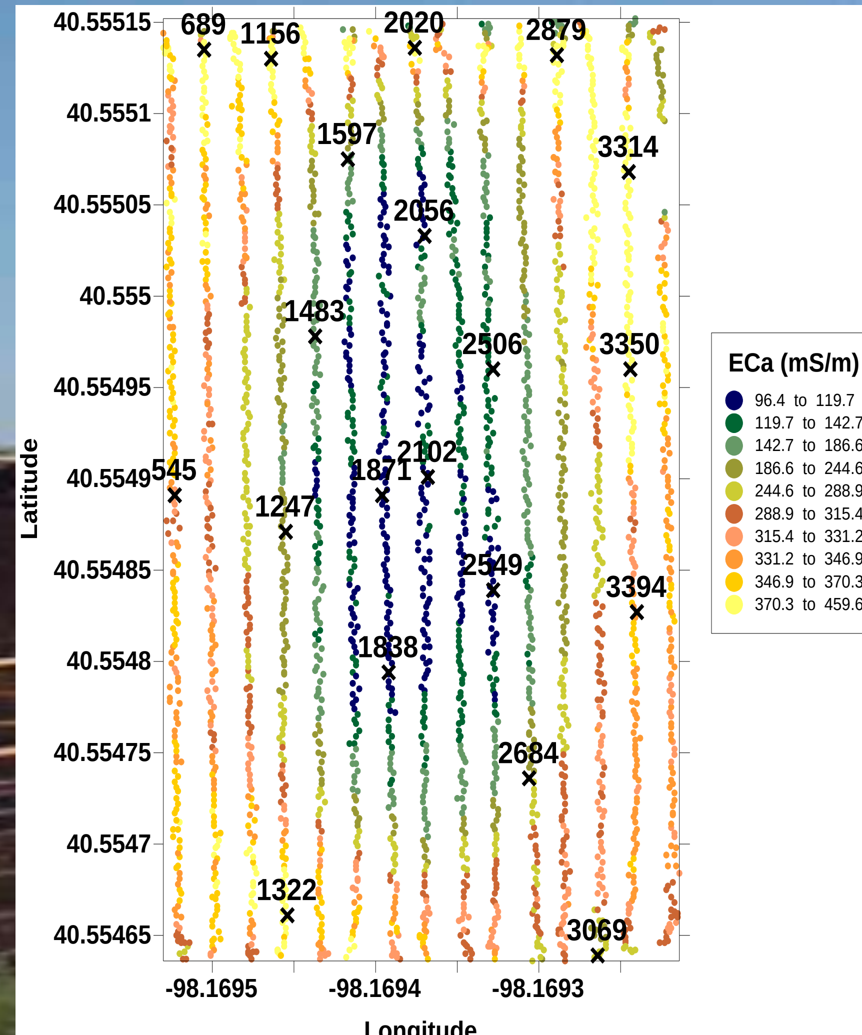
Response Surface Sampling Design (20 sites)

- Strategically pick sites to maximizes info on EC_a variation
- Evaluate spatial relationship to minimize auto-correlations
- Series of iterations to find the best set of sampling sites
- Use GPS coordinates to co-locate soil sample with EC_a value.

Stratified Random Sampling Design



Response Surface Sampling Design



Locating Sample Points Using GPS

Co-locating eliminates spatial uncertainty
Between EC_a value and soil sample

Soil property correlation matrix, and soil property/EMI cross-correlation estimates.

Soil property correlation matrix (n = 40)

	ln(Cl)	TN	TP	VS
ln(Cl)	1.000	0.898	0.924	0.913
TN		1.000	0.985	0.987
TP			1.000	0.978
VS				1.000

Soil property / EMI cross-correlation estimates (n = 40)

	ln(Cl)	TN	TP	VS
EMI	0.931	0.863	0.865	0.881
ln(EMI)	0.966	0.924	0.930	0.937

Objective 1: RSSD vs. SRS
Sampling Design Scores

- D optimality (D_{opt}) is a measure of the expected precision of the regression model parameter estimates

Sampling Plan	Sample Design Optimality Score		
	D_{opt}	V_{opt}	G_{max}
Response Surface Sampling Design (RSSD)	$1.52 \cdot 10^{-2}$	1.123	1.231
Stratified Random Sampling (SRS)	$0.22 \cdot 10^{-2}$	1.178	1.989

Objective 1: RSSD vs. SRS
Sampling Design Scores

- D optimality (D_{opt}) is a measure of the expected precision of the regression model parameter estimates
- V optimality (V_{opt}) is a measure of the expected average prediction error associated with the regression model predictions

Sampling Plan	Sample Design Optimality Score		
	D_{opt}	V_{opt}	G_{max}
Response Surface Sampling Design (RSSD)	$1.52 \cdot 10^{-2}$	1.123	1.231
Stratified Random Sampling (SRS)	$0.22 \cdot 10^{-2}$	1.178	1.989

Objective 1: RSSD vs. SRS
Sampling Design Scores

- D optimality (D_{opt}) is a measure of the expected precision of the regression model parameter estimates
- V optimality (V_{opt}) is a measure of the expected average prediction error associated with the regression model predictions
- **G maximum (G_{max}) is a measures of the expected maximum prediction error of the regression model predictions.**

Sampling Plan	Sample Design Optimality Score		
	D_{opt}	V_{opt}	G_{max}
Response Surface Sampling Design (RSSD)	$1.52 \cdot 10^{-2}$	1.123	1.231
Stratified Random Sampling (SRS)	$0.22 \cdot 10^{-2}$	1.178	1.989

Objective 2: RSSD Ability to Predict SRS Values

Quadratic regression model summary statistics and parameter estimates for each sampling design.

Variable	Design	R^2	Root MSE	$\beta_0\,(se)$	$\beta_1\,(se)$	$\beta_2\,(se)$
ln(Cl)	RSSD	0.953	0.104	1.389 (3.17)	1.650 (1.20)	-0.084 (0.11)
	SRS	0.937	0.086	1.796 (4.91)	1.501 (1.84)	-0.068 (0.17)
TN/1000	RSSD	0.928	1.84	-246.7 (55.5)	88.0 (21.0)	-7.29 (1.96)
	SRS	0.884	1.81	-276.0 (100.2)	97.9 (37.6)	-8.12 (3.52)
TP/1000	RSSD	0.948	0.472	-83.0 (14.3)	29.8 (5.39)	-2.50 (0.50)
	SRS	0.920	0.471	-87.9 (26.1)	31.1 (9.81)	-2.58 (0.92)
VS	RSSD	0.946	3.72	-528.2 (112.4)	186.9 (42.5)	-15.3 (3.97)
	SRS	0.882	4.40	-500.6 (243.8)	173.0 (91.6)	-13.7 (8.56)

Objective 2: RSSD Ability to Predict SRS Values (cont.)

RSSD samples were calibration data, SRS samples were independent validation sites.

Variable	Composite F-test F score (*P*>F)	Joint Prd F-test F score (*P*>F)	Mean Prd *t*-test *t* score (*P*>F)
ln(Cl)	1.98 (0.136)	0.86 (0.630)	2.14 (0.047)
TN	0.36 (0.785)	0.87 (0.618)	-0.49 (0.628)
TP	0.97 (0.420)	0.99 (0.516)	-0.72 (0.484)
VS	0.50 (0.682)	1.28 (0.307)	-0.48 (0.640)

- **Composite F-test** demonstrates parameter estimates for both sampling designs are equivalent.

Objective 2: RSSD Ability to Predict SRS Values (cont.)

Response surface sampling design (RSSD) samples used as calibration data, stratified random sampling (SRS) samples used as independent validation sites.

Variable	Composite F-test F score (*P*>F)	Joint Prd F-test F score (*P*>F)	Mean Prd *t*-test *t* score (*P*>F)
ln(Cl)	1.98 (0.136)	0.86 (0.630)	2.14 (0.047)
TN	0.36 (0.785)	0.87 (0.618)	-0.49 (0.628)
TP	0.97 (0.420)	0.99 (0.516)	-0.72 (0.484)
VS	0.50 (0.682)	1.28 (0.307)	-0.48 (0.640)

- Composite F-test demonstrates parameter estimates for both sampling designs are equivalent.
- **Joint Prd. F-test demonstrates that RSSD can accurately predict SRS values**

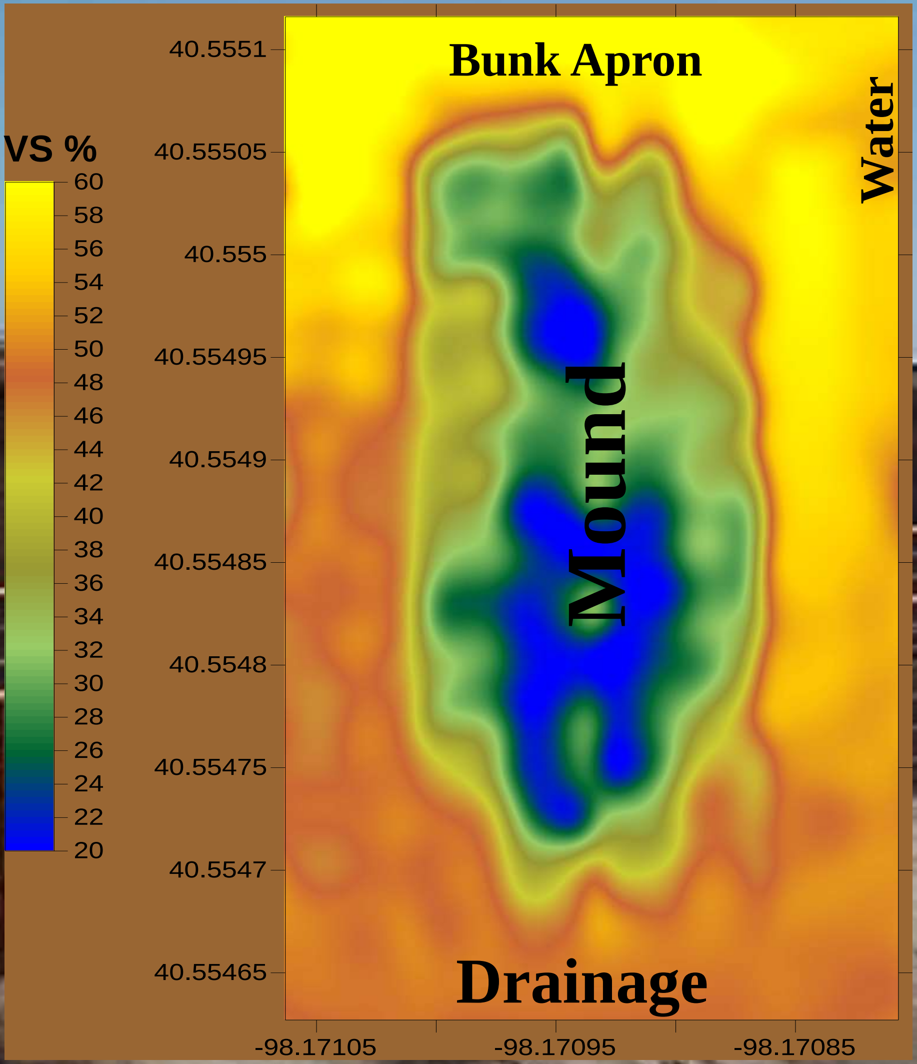
Objective 2: RSSD Ability to Predict SRS Values (cont.)

Response surface sampling design (RSSD) samples used as calibration data, stratified random sampling (SRS) samples used as independent validation sites.

Variable	**Composite F-test** F score (*P*>F)	**Joint Prd F-test** F score (*P*>F)	**Mean Prd *t*-test** *t* score (*P*>F)
ln(Cl)	**1.98 (0.136)**	**0.86 (0.630)**	**2.14 (0.047)**
TN	**0.36 (0.785)**	**0.87 (0.618)**	**-0.49 (0.628)**
TP	**0.97 (0.420)**	**0.99 (0.516)**	**-0.72 (0.484)**
VS	**0.50 (0.682)**	**1.28 (0.307)**	**-0.48 (0.640)**

- **Composite F-test demonstrates parameter estimates for both sampling designs are equivalent.**
- **Joint Prd. F-test demonstrates that RSSD can accurately predict SRS values**
- **Mean Prd. T-test demonstrate means were unbiased for TN, TP, VS**

Objective 3 & 4: Spatial Structure & Management Practices



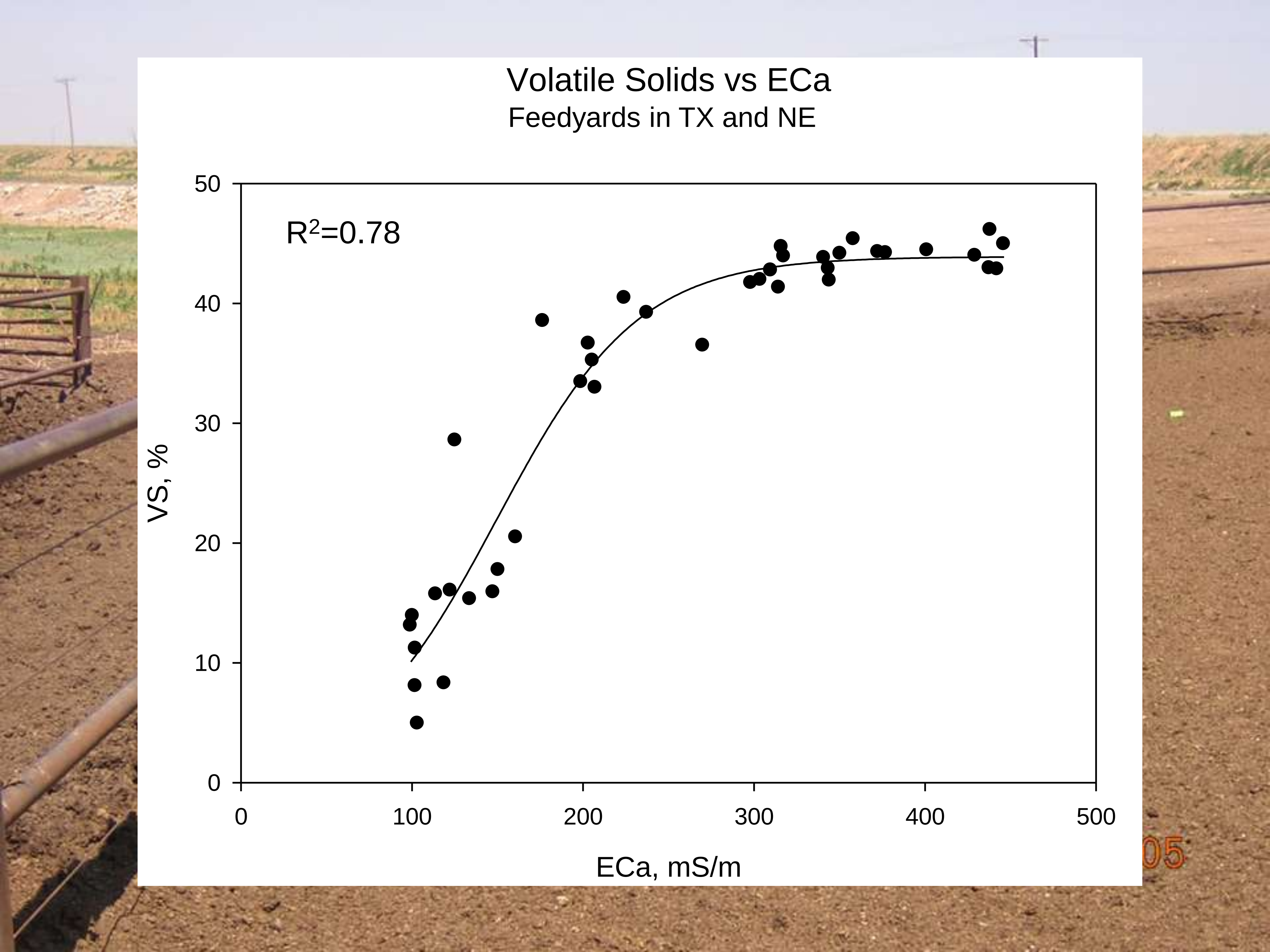
Conclusions

1. **Three different validation tests were used to assess the accuracy and reliability of the RSSD fitted model.**
   - **RSSD was found to be as good or better than SRS.**

2. **The excellent correlations between the PRP EMI signal data and the ln(Cl), TN, TP and VS soil properties.**
   - **Each of the four models was capable of explaining more than 90% of the sample variations.**
   - **EMI data can be effectively used to map spatially variable manure constituents in feedlot pens.**

3. **Prediction maps show pen design effect on manure accumulation**

4. **This technique allow the development of precision management practices to mitigate environmental contamination environment.**


Volatile Solids vs ECa
Feedyards in TX and NE
R^2=0.78
VS, %
ECa, mS/m
0
10
20
30
40
50
0
100
200
300
400
500

Spatial Feedlot Manure Accumulation

ECa Data with GPS Coordinates → **ESAP - RSSD** → **Sample Locations** co-located w/EMI

Soil Core
VS, TN, TP, Cl,
CO_2, N20, CH_4,
VFA, Aromatics

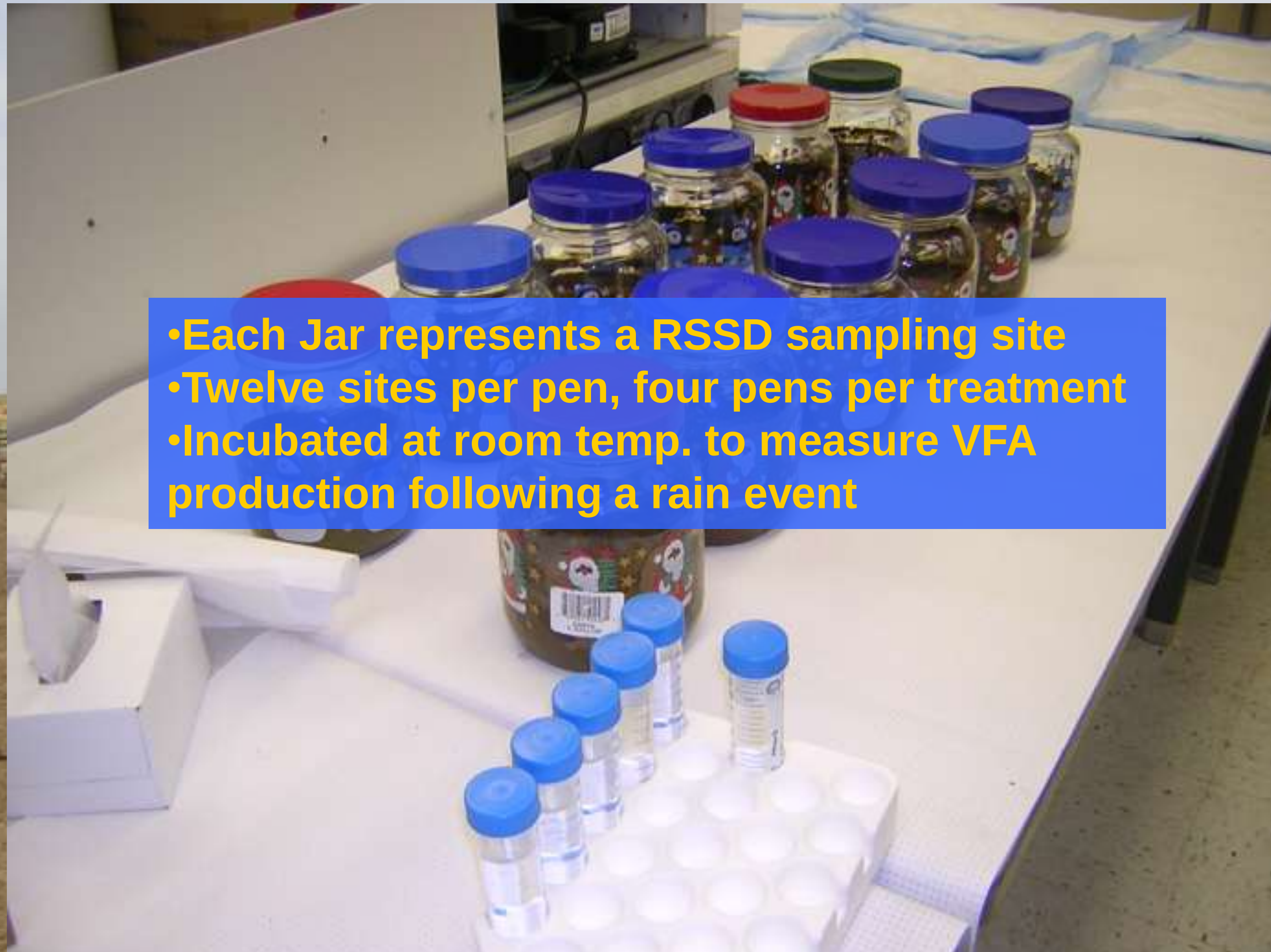
ECa Data

→ **ESAP - Calibrate** →

Calculate Models
Summary Statistics
Prediction Equations
Prediction Maps

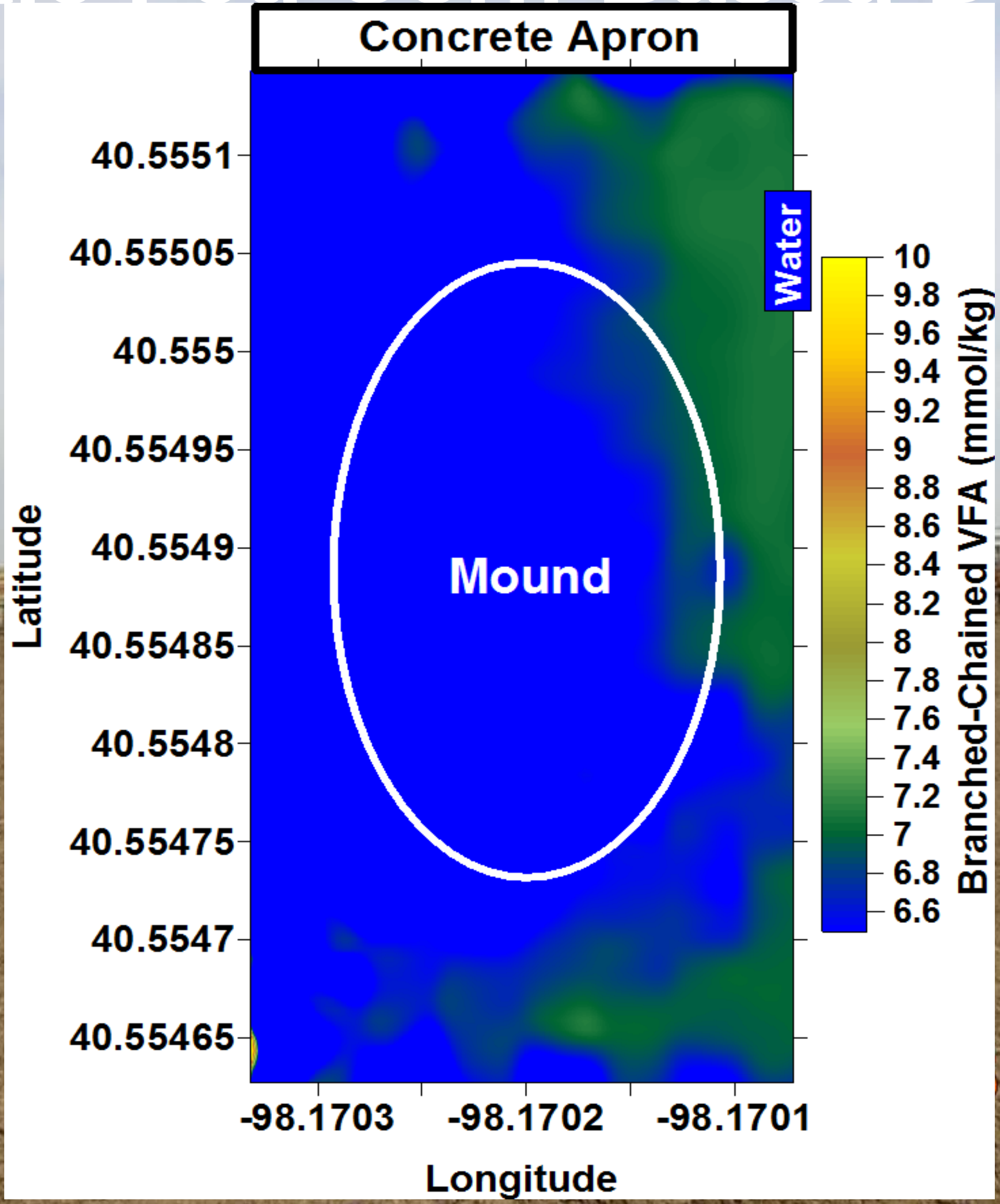
05.18.2004

Using EMI to Measure Treatment Differences (Corn vs. WDGS)

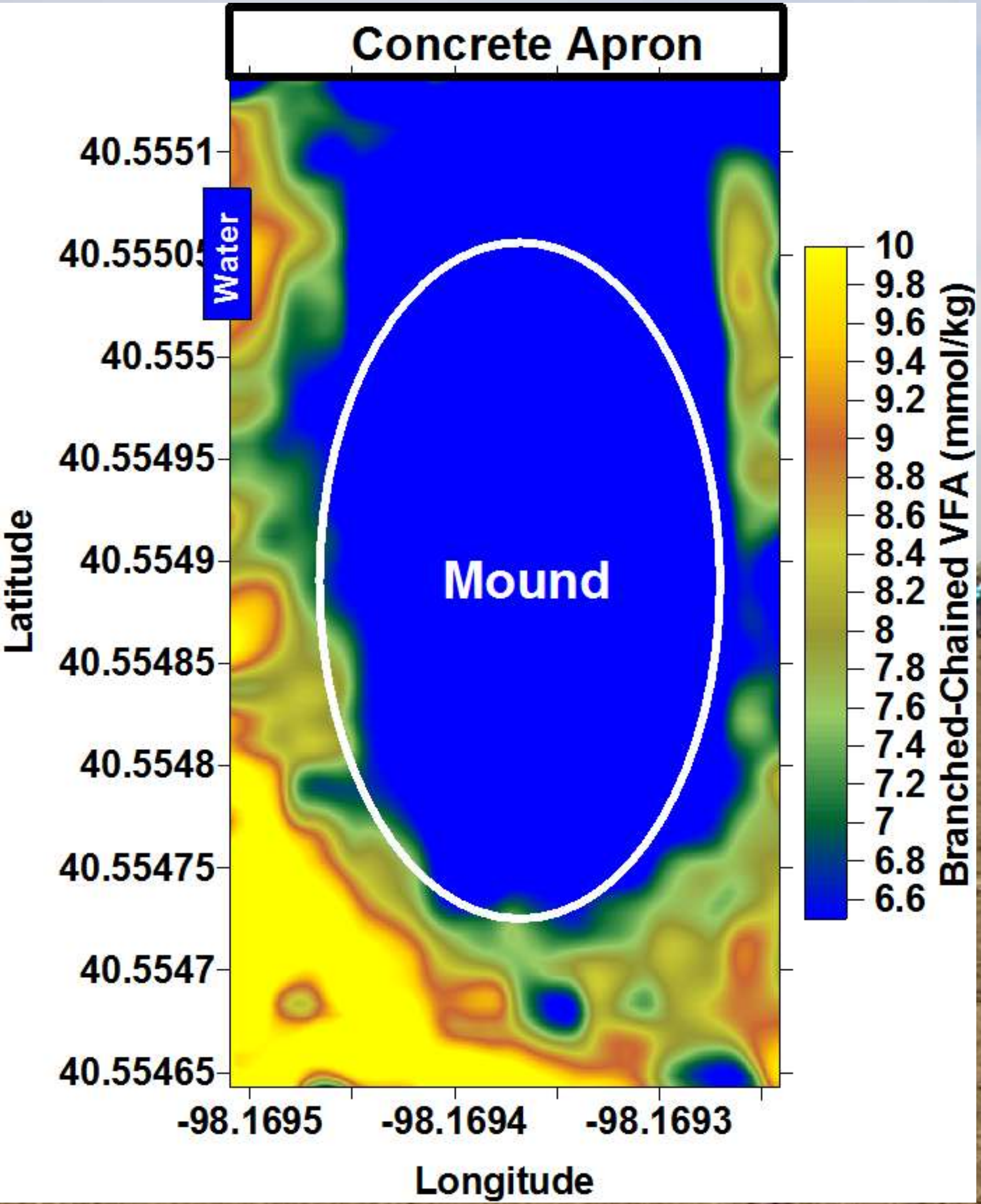


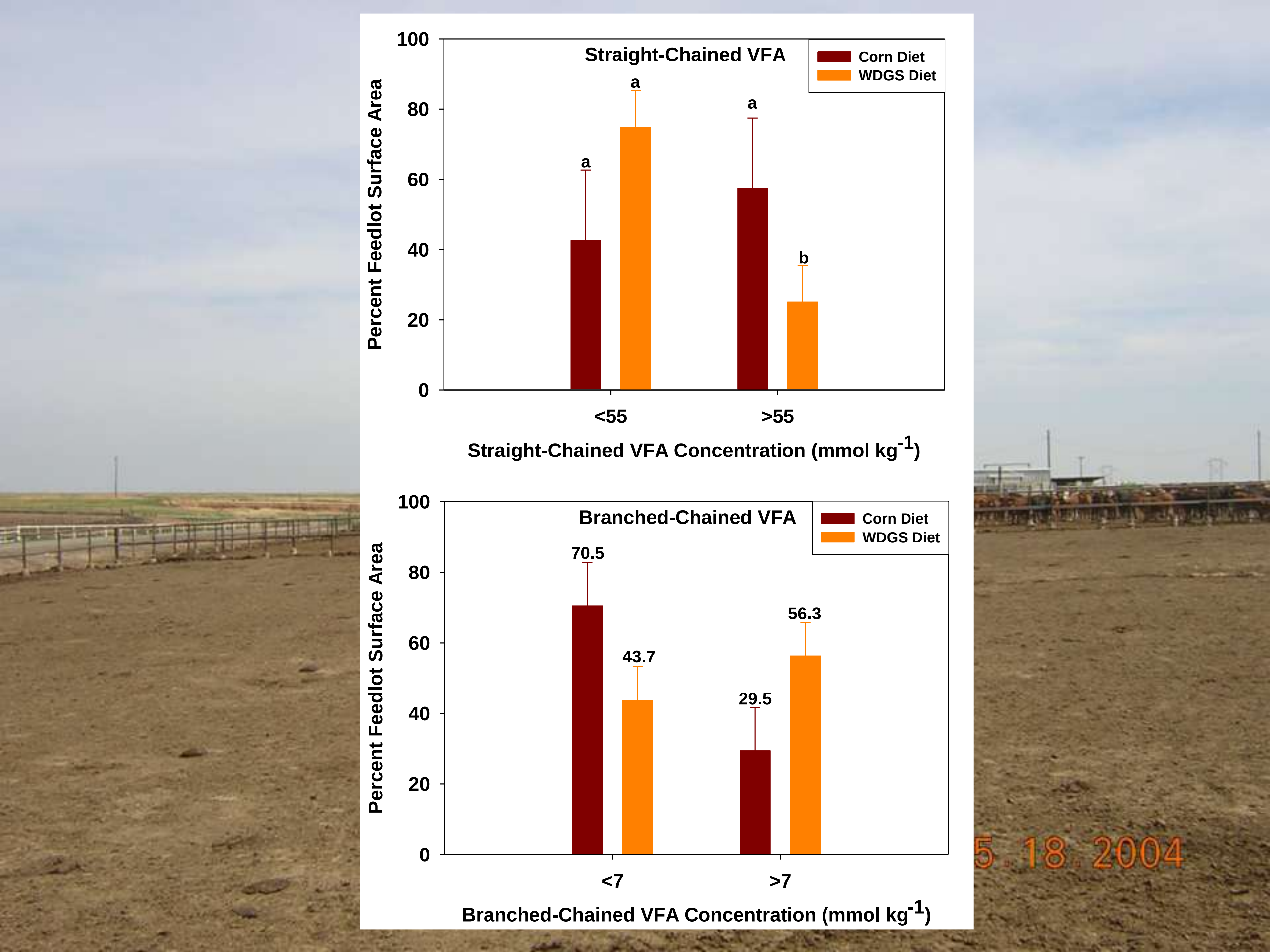
- Each Jar represents a RSSD sampling site
- Twelve sites per pen, four pens per treatment
- Incubated at room temp. to measure VFA production following a rain event

Cattle Fed Corn-Based Diet

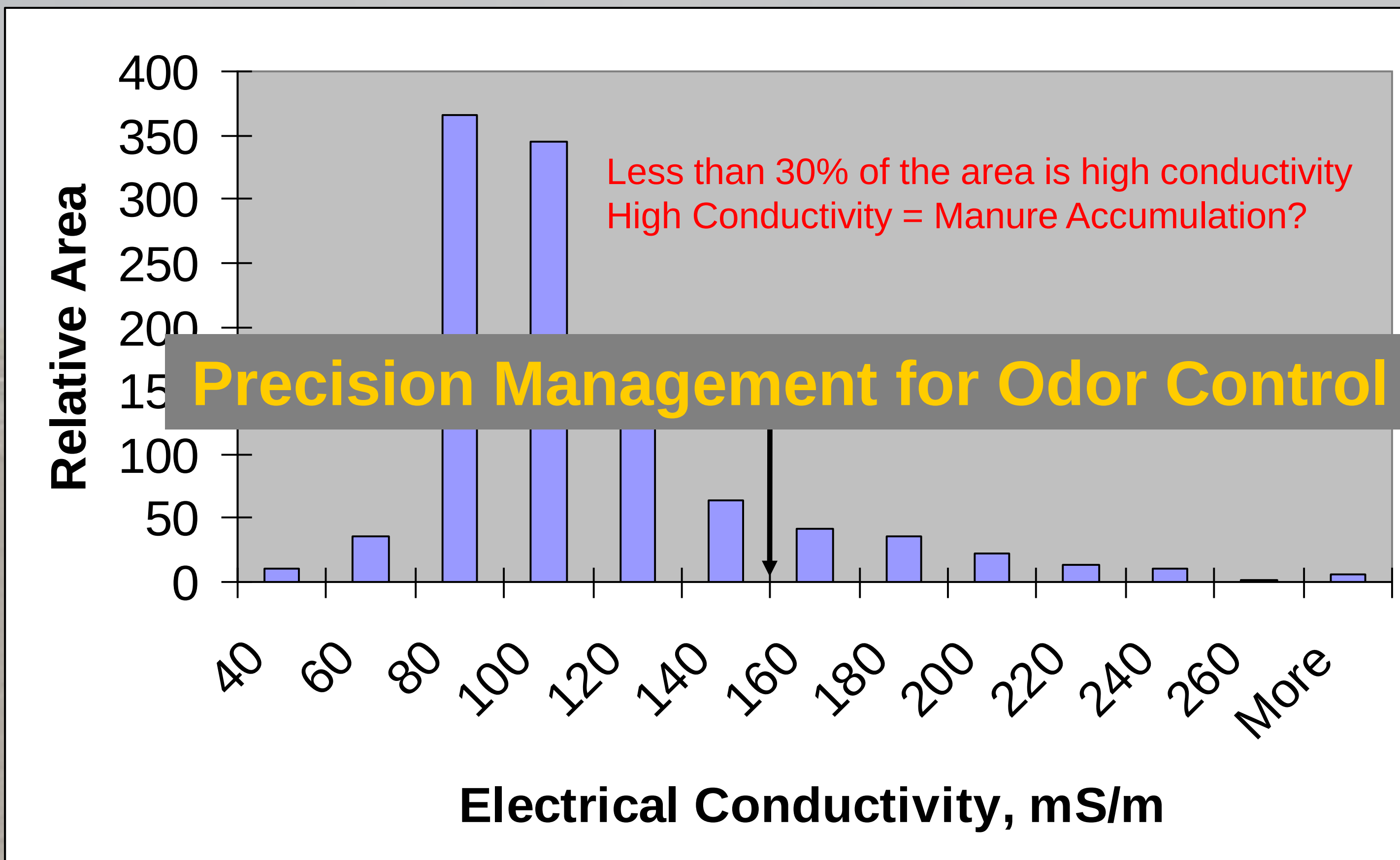


Cattle Fed WDGS-Based Diets

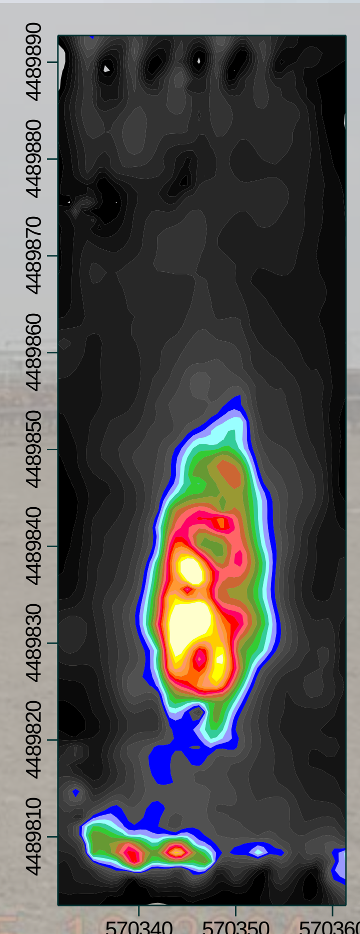



Straight-Chained VFA
Corn Diet
WDGS Diet
Percent Feedlot Surface Area
100
80
60
40
20
0
a
a
a
b
<55
>55
Straight-Chained VFA Concentration (mmol kg^{-1})
Branched-Chained VFA
Corn Diet
WDGS Diet
Percent Feedlot Surface Area
100
80
60
40
20
0
70.5
43.7
29.5
56.3
<7
>7
Branched-Chained VFA Concentration (mmol kg^{-1})
5.18.2004

Small Area of Pen with Offending Emissions



Precision Management for Odor Control



Questions

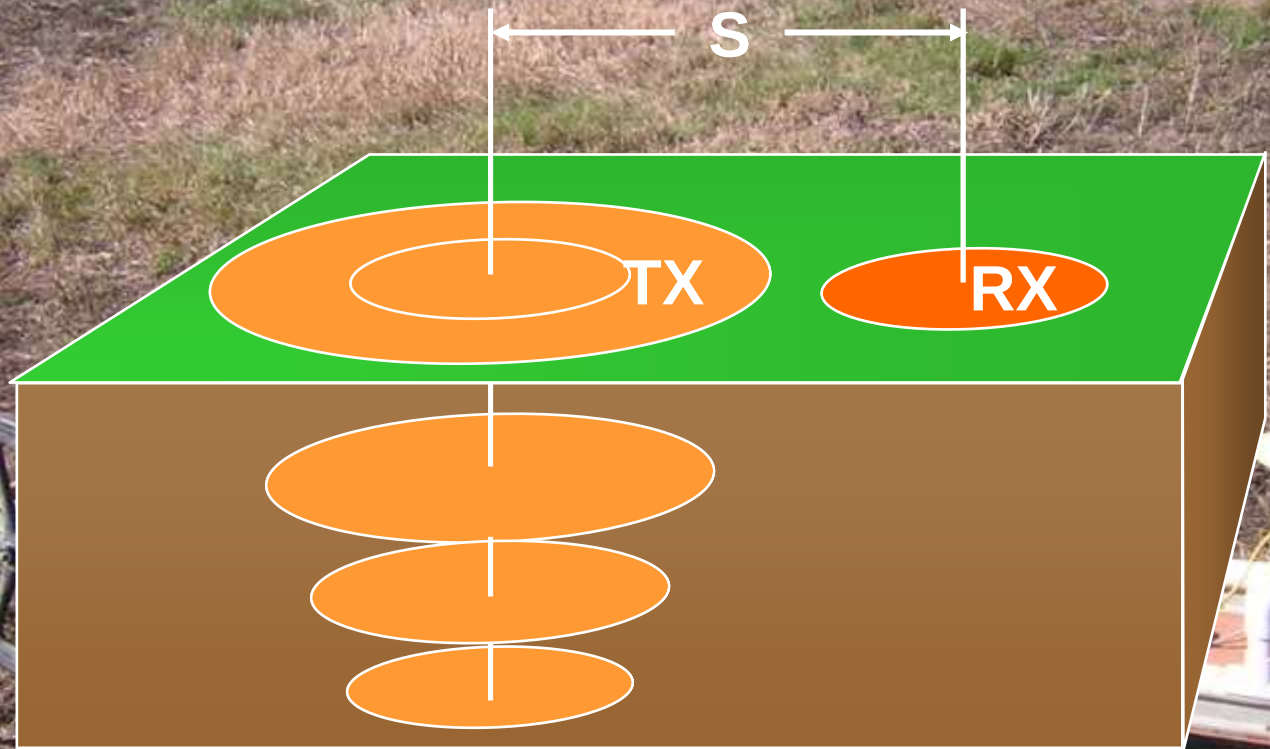
Percent surface area above or below a selected threshold level for each pen. Note mean values follow by different letter were significantly different by diet at the p ≤ 0.1 level.

Pen	Diet	Acetate		Straight-chain VFA		Branched-chain VFA		Total VFA		Solids	
		<65	>65	<55	>55	<7.0	>7.0	<130	>130	<30	>30
		mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	%	%
217	Corn	16.4	83.6	22.1	77.9	80.0	20.0	21.2	78.8	12.9	87.1
218	Corn	60.4	39.6	55.5	44.5	73.5	26.5	64.9	35.1	72.4	27.6
223	Corn	21.9	78.1	29.2	70.8	52.7	47.3	26.9	73.1	14.4	85.6
224	Corn	54.5	45.6	63.6	36.4	76	24	60.9	39.1	41.8	58.2
Average		38.3a	61.7a	42.6a	57.4a	70.6a	29.4a	43.5a	56.5a	35.4a	64.6a
219	WDGS	66.6	33.4	79.0	21.0	57.8	42.2	75.6	24.4	53.1	46.9
220	WDGS	100	0	60.3	39.7	37.4	62.6	92.2	7.8	83.3	16.7
221	WDGS	43.4	56.6	75.7	24.3	41.3	58.7	59.2	40.8	59.9	40.1
222	WDGS	64.9	35.1	84.7	15.3	38.4	61.6	76.0	24.0	63.2	36.8
Average		68.7a	31.3a	74.9b	25.1b	43.7b	56.3b	75.8b	24.2b	64.9a	35.1a
P-value		0.191	0.191	0.040	0.040	0.015	0.015	0.081	0.081	0.135	0.135


07 02 2004

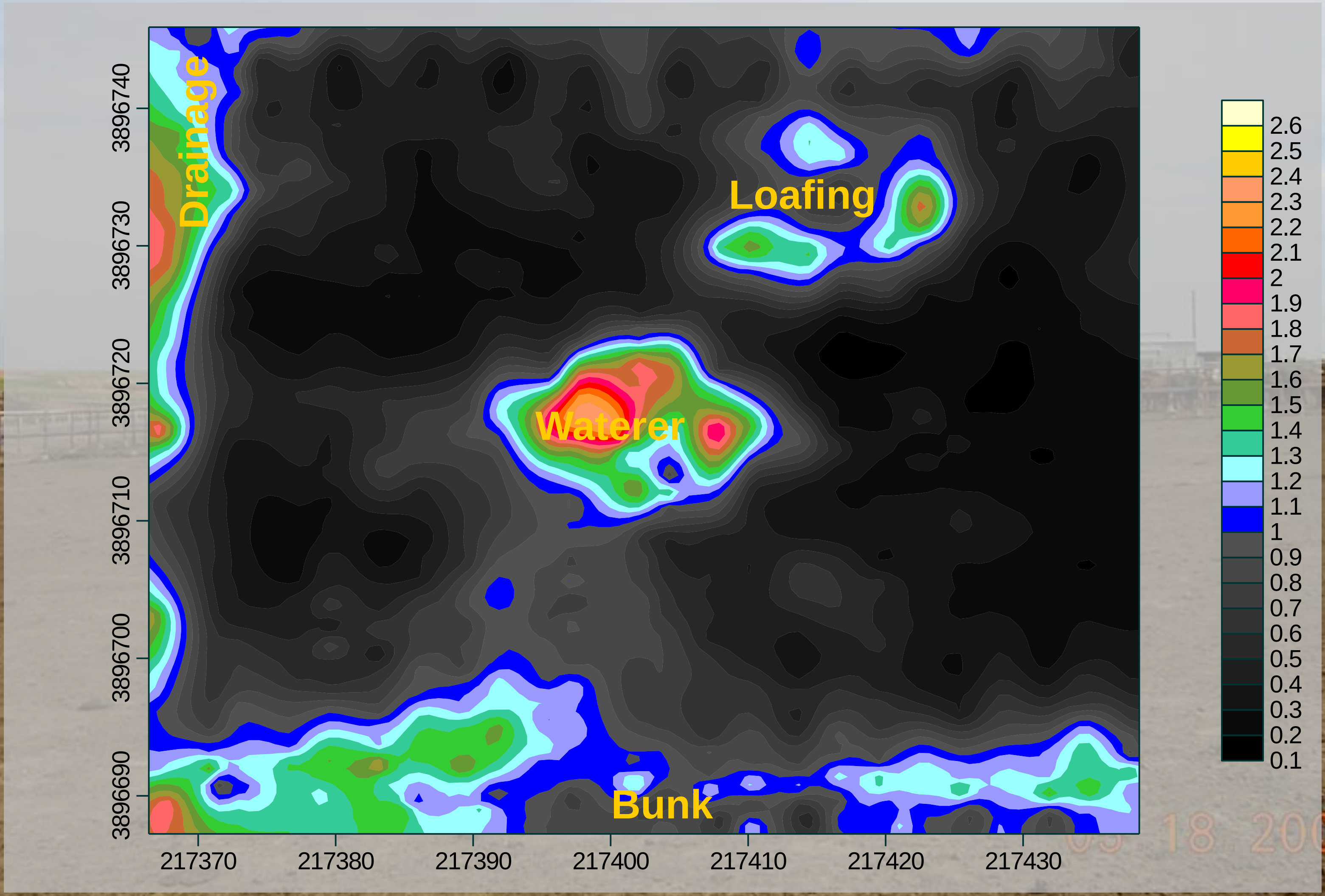
Electromagnetic Soil Conductivity Meter, ECa

Electromagnetic Induction Principles

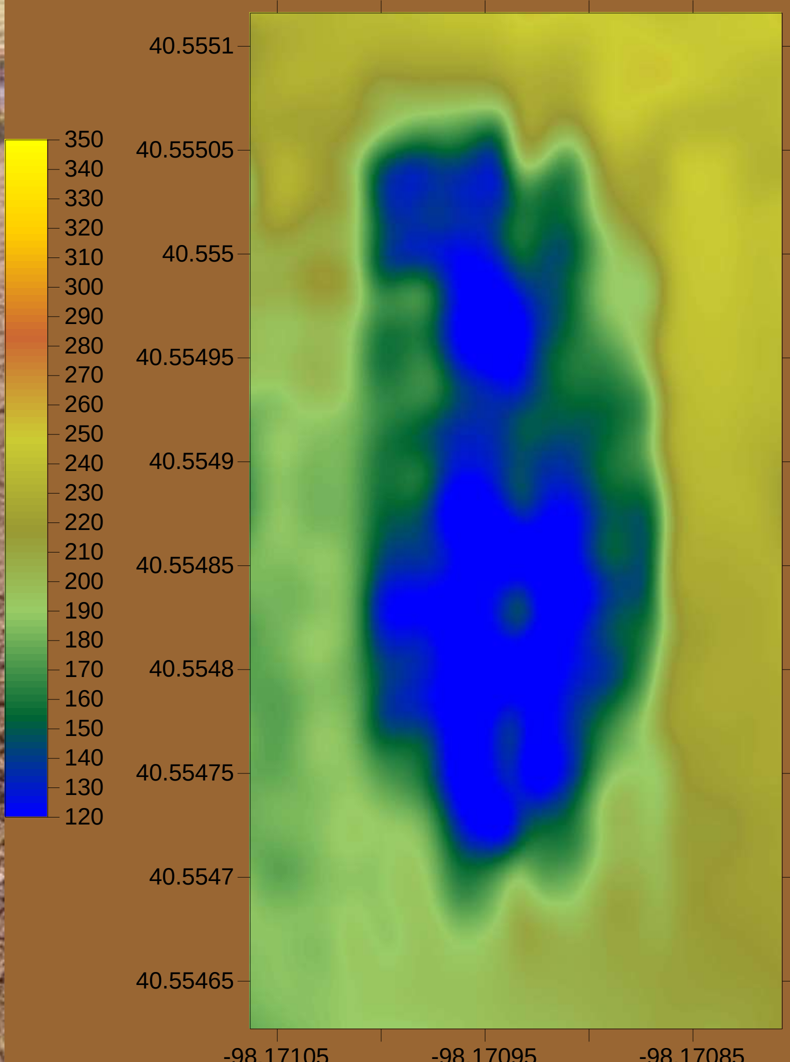


The transmitter coil (TX) is placed near the earth and is energized with an alternating current. The small currents induced into the earth generate a secondary signal which is picked up by a receiver coil (RX) at a distance S away. The ratio of the two signals gives a measure of the soil's conductivity beneath the two coils.

Feedlot Survey Bushland, TX



2 days, 22 deg C, total Volatile Fatty Acids (mmole/Kg dry matter)



4 days, 22 deg C, total Volatile Fatty Acids (mmole/Kg dry matter)